Full Simulation Studies of the Silicon Tracker for the Linear Collider Detector *

M. Iwasaki [†]

Dept. of Physics, University of Tokyo,
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0011 JAPAN

Abstract

A central tracker based on silicon microstrip sensors has been envisaged for the e^+e^- linear collider experiments. A full simulation program based on GEANT4 has been developed to study performance of the tracker. We report some preliminary results obtained using this program.

The use of silicon microstrip detectors as precise tracking devices in colliding-beam experiments has been well established. The silicon microstrip detector is used as a vertex detector mounted immediately outside the beam pipe to reconstruct the decay vertices of short-lived particles. The robustness of the silicon vertex detector against beam backgrounds has also been demonstrated. At the SLAC Linear Collider (SLC) experiment, excessive occupancy due to the accelerator originated backgrounds in the central tracking drift chamber limited its operation. Because the anticipated accelerator-induced background of the future e^+e^- linear collider (LC) is severer than that of SLC, the silicon microstrip detector has emerged as a promising candidate for a central tracking device.

In this report, we summarize preliminary results obtained based on a full simulation of the silicon microstrip central tracker. For the detector configuration, we use the parameters considered for the NLC SD silicon tracker[1], consisting of five

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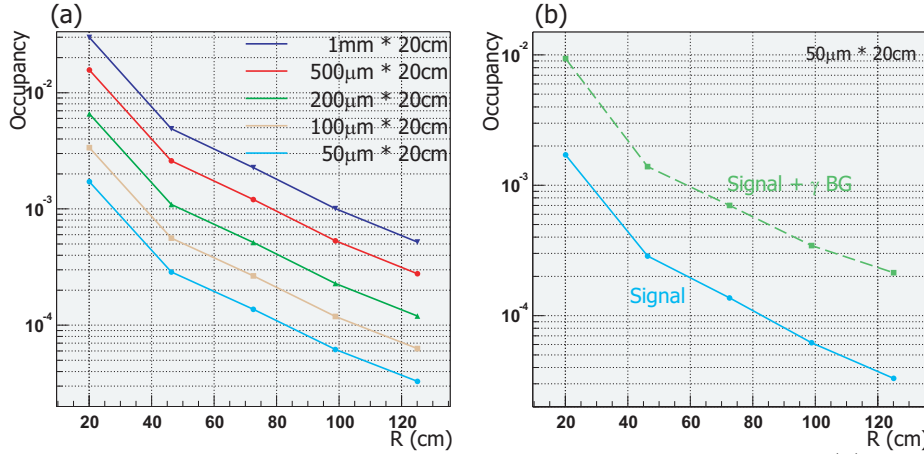[†]e-mail address: masako@phys.s.u-tokyo.ac.jp

Figure 1: Occupancy distributions as a function of the radius, (a) for signal only with different strip-pitch sizes, and (b) for signal only (solid line) and signal plus photon background at the IR (dashed line).

concentric double-sided silicon microstrip layers located at radii between 20cm and 125cm, immersed in the magnetic field of 5 Tesla. The thickness of each layer is assumed to be 0.5% of one radiation length. GEANT4[2] is used to simulate detector hits and generated hit positions are smeared by a resolution of 7μm. In order to reconstruct the track, the hits belonging to a particle are grouped and the track fitting program using Kalman filter is applied to the hits. Throughout the study presented here, we assume the center-of-mass energy of 500GeV.

Figure 1(a) shows the occupancy of the silicon layer as a function of its radial position. We use the high multiplicity events of $e^+e^- \rightarrow t\bar{t} \rightarrow 6$ jets. The strip length is assumed to be 20 cm while the strip pitch varies from 50μm to 1mm. We find that the occupancy of the innermost layer is $10^{-3} - 10^{-2}$, depending on the pitch size, for signal-only events.

The simulation of the interaction region (IR) indicates that the tracking system is expected to have photon backgrounds from unconverted beamstrahlung radiations. To estimate the effects caused by the background we generate beamstrahlung photon backgrounds using the IR simulation, feed them to the GEANT4 detector simulation, and superimpose the resulting hits to the signal hits. For the NLC accelerator parameter of 190 bunches/train, we find ~ 34000 photons with the average energy of 1 MeV are produced in an event. Of those produced photons about 2000 photons
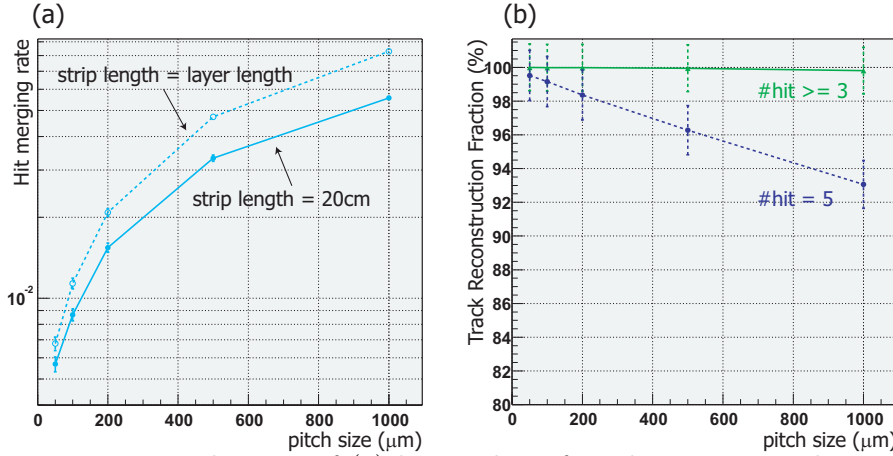
Figure 2: Distributions of (a)the number of tracks traversing the same $r - \phi$ strip and (b) the track reconstruction efficiency only using $r - \phi$ strips, for various pitch sizes.

with the average energy of 0.7 GeV generate hits in the tracker. We find that one photon generate 1.04 hits on average. The resulting occupancy is shown as a dashed line in Fig.1(b). The occupancy is an order of magnitude higher than that of signal-only events, but still remains low enough ($\sim 1\%$) even at the innermost layer.

In order to study the two-track separation capability of the silicon detector, we generate events with high track density (jet events), $e^+e^- \rightarrow q\bar{q}$ ($q = uds$), and investigate the minimum distance, within each silicon layer, between two hits belonging to different tracks. We find the minimum distance of 100μm, 500μm, and 1mm in the first, third and fifth layer, respectively. Figure 2(a) shows the multiple-hit rate in a strip for various pitch sizes. The hits belonging to the same strip is indistinguishable if we use only $r - \phi$ information. For the pitch size less than 200μm, only about 1% of $r - \phi$ strips have more than one hits. Figure 2(b) shows the track reconstruction efficiency estimated using the $r - \phi$ information *only*. Even using only $r - \phi$ hits we find that the reconstruction efficiency is greater than 99% assuming we we reconstruct tracks with a minimum of 3 layers. If we require a minimum of 5 layers for track reconstruction, we lose the efficiency because some hits are merged for larger pitch sizes. (This loss, however, can be recovered using the z information provided by stereo strips.)

Figure 3(a) shows the track reconstruction efficiency as a function of the track momentum, for using the central tracker only (solid lines) and using the central
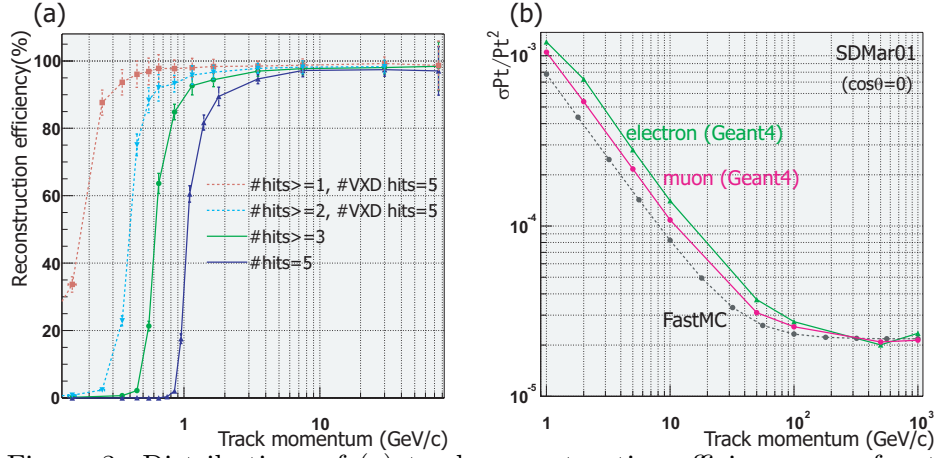
Figure 3: Distributions of (a) track reconstruction efficiency as a function of the momentum for the central tracker only (solid) and for the central tracker plus vertex detector(dashed), and (b) the transverse momentum resolution obtained for the central tracker plus vertex detector.
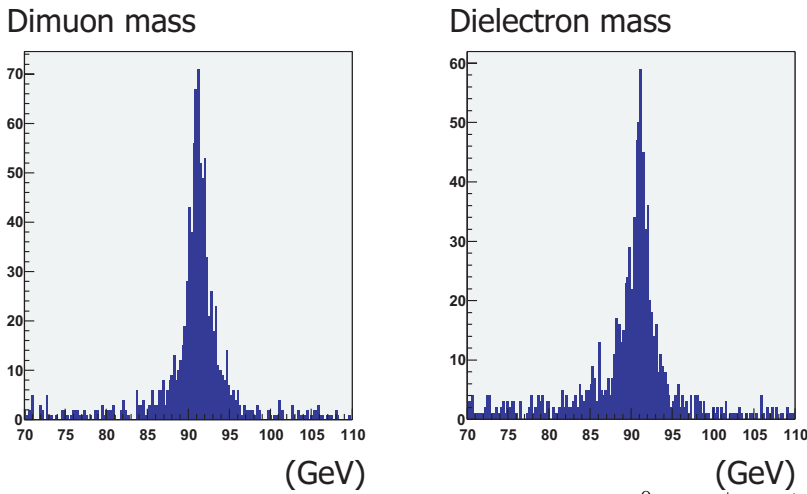

Figure 4: Reconstructed mass distributions for $Z^0 \to \mu^+\mu^-$ (left) and $Z^0 \to e^+e^-$ (right) decays, in $e^+e^- \to Z^0H^0$ events .

tracker and vertex detector (dashed lines). Because the solenoid field is high (5 Tesla), the presence of the vertex detector is important to reconstruct the low momentum tracks. Figure 3(b) shows the transverse momentum resolution as a function of the track momentum obtained using the central tracker and vertex detector. Here the single track is generated at a zero dip angle (perpendicular to the beam axis). To further study the momentum resolution, we reconstruct the Z mass, in $e^+e^- \rightarrow Z^0H^0$, $Z^0 \rightarrow l^+l^-$ ($l = e$ or μ) events. Figure 4 shows dimuon and dielectron mass distributions obtained using a full simulation. The Z mass resolution is 1.7 GeV and 1.9 GeV for $Z \rightarrow \mu^+\mu^-$ and e^+e^-, respectively.

We note that it is important to use a realistic track-finding algorithm for further study. In order to estimate the accelerator background, the beam delivery system (BDS) simulation is also important. Using a newly developed BDS simulation package, LCBDS[3], based on GEANT4, we plan to study the effects due to IR backgrounds.

References

[1] American Linear Collider Working Group (T. Abe *et al.*), [hep-ex/0106058].

[2] http://wwwinfo.cern.ch/asd/geant4/description.html

[3] H. Aihara, M.Iwasaki and K.Tanabe, [hep-ex/0303015].